

JSC Policy Directive

JPD 1830.3H

EFFECTIVE DATE: 6/09/03

EXPIRATION DATE: 6/09/08

RESPONSIBLE OFFICE: SA/Space and Life Sciences

SUBJECT: Limitations Applicable to Personnel Exposed to Diving

1. POLICY. It is JSC policy to maximize safety by defining limits that minimize the risk of decompression sickness following diving and/or flying activities.

2. SCOPE AND APPLICABILITY. This Policy Directive is applicable to all JSC organizational elements participating in diving or flying activities. Personnel who come within the scope of this Policy Directive include: astronauts, test subjects and support personnel, and contractor personnel participating in diving and/or flying activities under JSC cognizance. Circumstances within the scope of this Policy Directive include: diving under JSC cognizance, flying in non-JSC (e.g., commercial) aircraft after diving under JSC cognizance, flying in JSC aircraft after any type of diving, participating at reduced pressure in hypobaric chamber tests after any type of diving, and training persons who do proficiency dives. This Policy Directive is not intended to restrict scientific research conducted with the approval of the JSC Institutional Review Board (IRB), nor does it apply to a person who is under the care of a physician for the treatment of decompression sickness.

3. DEFINITIONS.

3.a. Diver and Diving. Refer, respectively, to personnel and activities involving exposures to hyperbaric conditions through either immersion or pressurization in a chamber.

3.b. Decompression Sickness. An illness caused by the formation of inert gas bubbles in body tissues as the result of a transition to an environment with a lower ambient pressure following a long and/or deep dive.

3.c. Facility Depth (FD). The location, in ft, beneath the surface of the water, of the following: (1) the center of the chest for a diver not enclosed in a pressurized suit and (2) for a diver enclosed in a pressurized suit, the gas regulator that controls suit inflation pressure.

3.d. Physiologic Depth (PD). The facility depth plus any depth equivalent imposed by pressurization of a suit $1 \text{ (pounds per square inch) psi} = 2.3 \text{ ft of depth}$; fractions should be rounded to the next-larger whole foot. For example, a suit pressurized with air at 4.0 psi differential pressure (psid) imposes a pressure equivalent to 10 ft of depth: $PD = FD + 10 \text{ ft}$. For a diver not enclosed in a pressurized suit, $PD = FD$.

3.e. Nitrox. A breathing gas with an oxygen content greater than that of air, balance nitrogen and trace gases.

3.f. Equivalent Air Depth (EAD). EAD is determined as: $EAD = (FIN2 (PD + 34)/0.79) - 34$ where FIN2 = Fraction of Inspired Nitrogen and PD = Physiologic Depth. The concept of EAD is applicable to diving while breathing Nitrox.

3.g. Decompression Diving. An operation that requires halts or "stops" at specific depths (or pressures greater than 14.7 absolute psia) for specified lengths of time in order to eliminate dissolved inert gases from body tissues.

*3.h. Flying. Refers to exposure to hypobaric conditions through operations in aircraft or hypobaric chambers. During aircraft operations, the cabin altitude, not the aircraft altitude, shall be applicable to this Policy Directive. The nominal cabin altitude of an aircraft operated by a major air carrier is less than 10,000 ft. This includes flights of any duration.

3.i. Repetitive Dives. Multiple dives performed with an interval on the surface of less than 12 hours.

3.j. Surface Interval (SI). Time spent at surface pressure between a dive and a flight.

4. LIMITATIONS.

4.a. Decompression diving shall not be performed.

4.b. No diving shall exceed the No-Decompression Limit specified in Table 1. A dive may be made to a depth deeper than PD = 20 ft (or EAD = 20 ft while breathing Nitrox) for a period of time up to the No-Decompression Limit for that depth, then return to PD = 20 ft (or EAD = 20 ft) or less for an unlimited period of time.

4.b(1) JPD 1830.3H does not apply to medical personnel supporting hyperbaric treatments using U.S. NAVY Treatment Tables and procedures.

4.c. An inadvertent depth excursion to a depth deeper than planned represents a significant deviation from the dive's test plan. Reasonable and prudent measures shall be used to prevent inadvertent excursions. In the event of an inadvertent excursion, the following procedures apply:

4.c(1) Cumulative duration of excursions < 5 minutes and maximal PD attained within 10 ft of planned depth: no impact.

4.c(2) If paragraph 4.c(1) does not apply, adhere to rules specified in Table 1 for determination of duration and depth. If the dive can be safely terminated within the No-Decompression Limit specified in Table 1, then terminate the dive before reaching this limit. If the dive cannot be terminated within the No-Decompression Limit, then return as soon as possible to PD = 10 ft, contact the Medical Officer, and decompress for 35 minutes or as directed by the Medical Officer.

4.d. Severe decompression sickness can result from flying after diving. The risk of decompression sickness is minimized through air or oxygen breathing after a dive for a specified minimum time before flying. Accomplish this as follows:

4.d(1) Divers planning to fly to cabin altitudes of less than 1,000 ft shall have no restrictions on flying after diving.

4.d(2) Divers planning to fly at cabin altitudes between 1,000 and 10,000 ft shall comply with the appropriate Surface Interval specified in Table 1. Divers may assume that the nominal cabin altitude of an aircraft operated by a major air carrier is between 1,000 and 10,000 ft.

As stated in paragraph 4.b., a dive may be made to a depth deeper than PD = 20 ft (or EAD = 20 ft while breathing Nitrox) for a period of time up to the No-Decompression Limit for that depth, then return to PD = 20 ft (or EAD = 20 ft) or less for an unlimited period of time. In this case, determine the interval between diving and flying as though the entire dive had taken place at the deeper depth.

If more than one dive is conducted within a 12-hour period, then determine the interval between diving and flying by referring to Table 1, using as "Duration" and "Depth," respectively, the sum of the durations of all dives and the deepest depth attained in any dive.

If the duration of a dive exceeds the longest dive specified for the appropriate depth in Table 1, then 24 hours breathing air or 3 hours breathing 100% oxygen shall elapse before flying.

4.d(3) Divers planning to fly at aircraft cabin altitudes greater than 10,000 ft shall refrain from flying for at least 24 hours after diving.

*4.d(4) Divers planning to participate at reduced pressures in hypobaric chamber tests after any type of diving shall refrain from hypobaric exposure for at least 48 hours after diving. Prebreathe time is included as part of the 48-hour interval because hypobaric chamber exposures have higher decompression stress than flying.

4.e. Conduct Nitrox diving as follows: (1) calculate EAD from paragraph 3.f. and (2) refer to the "EAD" column in Table 1. The partial pressure of inspired oxygen shall not exceed 1.3 atmospheres absolute pressure (ata; 1 ata = 14.7 psi). The Cumulative Pulmonary Toxicity Dose calculated from Table 2 shall not exceed 694 units for a single day, 2100 units accumulated over 5 days, or 3000 units accumulated over 10 days. The accumulation of Pulmonary Toxicity Dose is reset to zero (0) by a 48-hour period of no Pulmonary Toxicity Dose. This means 48 hours without exposure to 100% oxygen, without diving with Nitrox, and without diving with compressed air below 45 ft.

4.f. Repetitive diving may be conducted in accordance with the procedures of the U.S. Navy Diving Manual except that the sum of the duration of the dive plus the "residual nitrogen time," if any, indicated by the U.S. Navy Diving Manual may not exceed the No-Decompression Limits specified in Table 1. If the "residual nitrogen time" cannot be determined from the U.S. Navy Diving Manual, then determine the "Duration" in Table 1 as the sum of the durations of the previous dive(s) and the planned repetitive dive, and determine the "Depth" as the deeper (deepest) depth attained in these dives.

5. RESPONSIBILITY. The Directors of Flight Crew Operations, Engineering, and Space and Life Sciences are jointly responsible for ensuring compliance with the requirements of this Policy Directive.

6. METRICS. Overall responsibility for collection of metrics lies with the Space and Life Sciences Directorate, which will perform annual reviews to ensure appropriate medical and administrative disposition. Findings and recommendations of annual reviews will determine adequacy of the Policy Directive and will be used for future revisions of this Policy.

6.a. Measurement will include total number of flights after flying after Neutral Buoyancy Laboratory (NBL) diving, and total number of prebreathes performed in accordance with this Policy Directive in both astronauts and support divers.

6.b. Measurement will include total number of incidents of decompression sickness (DCS) after NBL diving and DCS after flying after NBL diving in both astronauts and support divers.

6.c. Specific metrics of DCS are the same as delineated in JPG 1800.3, Decompression Sickness Procedures and Guidelines.

6.c(1) Total number of DCS cases correctly reported and administered.

6.c(2) Total number of DCS events not initially reported, but subsequently identified.

6.c(3) Total number of DCS events reported, but not correctly administered in accordance with the policy.

6.c(4) Percent adherence to all certification and monitoring requirements denoted in the Appendix of JPG 1800.3 for the tests being performed.

7. RESCISSION. JMI 1830.3G, August 22, 1994, is rescinded. This revision has been substantially rewritten and changes are not annotated.

4 Attachments:

1. Table 1 – No-Decompression Limits for Diving and Surface Intervals for Flying After Diving
2. Table 2 – Calculation of Cumulative Pulmonary Toxicity Dose (CPTD) Used In Nitrox Diving
- *3. JSC FCOD Dive/Fly Card
4. Hydrolab Operations

* denotes change.

<Original signed by Jefferson D. Howell, Jr. 6/09/03>

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JSC Director

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TABLE 1
NO-DECOMPRESSION LIMITS FOR DIVING AND SURFACE INTERVALS FOR
FLYING AFTER DIVING

PD = Physiologic Depth

EAD = Equivalent Air Depth

FD = Facility Depth

FD at 4.0 psid breathing Nitrox (46% \pm 1%) = specific for the JSC NBL for an astronaut breathing a Nitrox mixture (45% oxygen) with the extravehicular mobility unit or EMU pressurized at 4.0 psid.

No-Deco = No-Decompression Limit.

SI = Surface Interval at surface pressure before flight at cabin altitudes between 1,000 and 10,000 ft.

To determine the appropriate depth in this table, determine the greatest depth achieved during the dive and select the row greater than or equal to that depth.

PD or EAD (ft)	FD at 4.0 psid (ft)§ (46% \pm 1%)	No-Deco Limit (minutes)	Duration (minutes)	Air SI (hours)	OR Oxygen SI (minutes)
0-20	0-35	no limit	1-60	3	20
			61-100	5	40
			101-400	14	120
			>400	24	180
20-25	35-40	400	1-45	3	20
			46-80	5	40
			81-290	14	120
			291-400	24	180
25-30	n/a	240	1-35	3	20
			36-60	5	40
			61-240	14	120
30-35	n/a	190	1-30	3	20
			31-50	5	40
			51-190	14	120
35-40	n/a	150	1-25	3	20
			26-45	5	40
			46-150	14	120
40-50	n/a	100	1-20	3	20
			21-35	5	40
			36-100	14	120

Attachment 1 to JPD 1830.3H

During typical dives in a Space Shuttle EMU at the NBL, physiologic depth is recorded and never exceeds 25 ft. As a "rule of thumb" derived from this Table, if a 4-hour dive is performed to a physiologic depth of 25 ft or less, 14 hours should elapse before flying at a cabin altitude of 10,000 ft (refer to the table for details). Column 1 is applicable to all diving with any gas in any facility at any pressure.

§Column is a specific solution breathing Nitrox 46% \pm 1% at a suit pressure of 4.0 psid.

TABLE 2
CALCULATION OF CUMULATIVE PULMONARY TOXICITY DOSE (CPTD)
(USED IN NITROX DIVING)

For the deepest depth attained during the dive, calculate the partial pressure of oxygen in the inspired gas expressed as atmospheres absolute pressure (ata; 1 ata = 14.7 psi). Determine "k" from the table below. $CPTD = k * t$ where "t" is dive duration in minutes and "*" is arithmetic multiplication. Also, $CPTD = t * (2 * PPO_2 - 1) 1.3868$, and $t = CPTD / (2 * PPO_2 - 1) 1.3868$.

Partial Pressure of O₂ (ata)	k
0.50 or less	0
0.55	0.041
0.60	0.107
0.65	0.188
0.70	0.281
0.75	0.382
0.80	0.492
0.85	0.610
0.90	0.734
0.95	0.864
1.00	1.000
1.05	1.141
1.10	1.288
1.15	1.439
1.20	1.595
1.25	1.755
1.30	1.919

JSC FCOD DIVE / FLY CARD

RULES OF THUMB FOR FLYING WITHIN 24 HOURS OF:

SUITED DIVES (Nitrox):

- For standard 6-hour EMU NBL runs, if maximum pool depth ≤ 35 ft (*note: inform divers you need a modified weigh-out*), you must breathe 100% O₂ for 2 hours before flying commercial or T-38, and fly with cabin altitude $\leq 10,000$ ft MSL (T-38 FL250). For other time-depth combinations, consult the prebreathe table below.

SCUBA (Nitrox): (*note: the prebreathe table does not include air scuba*)

- Dives in the NBL for up to 60 minutes duration require a 20-minute 100% O₂ prebreathe before flying commercial or T-38, and you must fly with cabin altitude $< 10,000$ ft MSL (T-38 FL250). The 20-minute prebreathe may be performed during taxi and takeoff.
- For dives of greater length, consult the prebreathe table below.

CHAMBER RUNS:

After diving, you are required to have a 48-hour surface interval before participating in altitude/vacuum chamber runs.

Following an altitude/vacuum chamber run, commercial or T-38 flights with cabin altitude $\leq 10,000$ ft MSL (T-38 FL 250) can be performed after a 12-hour surface interval. There are no flight restrictions after a 24-hour surface interval.

IMPORTANT NOTES:

*If you must fly within 24 hours of a dive, then the cabin altitude must remain $\leq 10,000$ ft MSL (T-38 FL 250). There are no restrictions to flying 24 hours after a dive.

When T-38 flying after diving, it is highly recommended that regulator be set to 100% O₂.

For scuba diving, Aquarius, or training at other facilities not covered here, contact NBL physician.

SOURCES OF 100% O₂:

NBL: Hyperbaric Chamber (281-792-5721 to arrange). Helmet and mask not required.

T-38: Jet O₂ can be used for 20-minute prebreathe before takeoff. If required prebreathe is longer than 20 minutes, then the total prebreathe must be done in the NBL Hyperbaric Chamber.

QUESTIONS: Contact NBL physicians (281-792-5719/5720/5724).

PREBREATHE TABLE

(air)	(Nitrox)	(Nitrox)		Surface Interval Before Flying§	
Max Orlan Hydrolab Depth (ft) Attained	Max.Scuba NBL Depth (ft) Attained	Max. EMU NBL Depth (ft) Attained	Total Dive Time (minutes)	Air (hrs)	O ₂ (min)
0-20	0-40	0-35	1-60	3	20
			61-100	5	40
			101-400	14	120
			>400	24	180
21-25	-----	36-40	1-45	3	20
			46-80	5	40
			81-290	14	120
			291-400	24	180

§Must complete either the air or O₂ surface interval before flying.

Hydrolab Operations

1. Applicability. The purpose of this attachment is to clarify the limitations imposed by JPD 1830.3H on Orlan-DMA and EMU operations at Hydrolab when U.S. astronauts use these systems. If there is a discrepancy between this attachment and the main body of JPD 1830.3H, the main body of JPD 1830.3H takes precedence.

2. General Information. The Hydrolab uses compressed air as the primary breathing gas for neutral buoyancy training of extravehicular activity (EVA) crewmembers. Both EMU and Orlan spacesuits are used in this EVA training. At the Hydrolab, the Orlan operates at 0.4 atm (5.9 psid) and the EMU operates at 0.27 atm (4.0 psid). The maximum depth of the Hydrolab facility is 10 m (33.3 ft). The pressure regulator on the Orlan-DMA suit is located on the crewmember's chest. The pressure regulator on the EMU suit is located about 8 cm below the waist ring.

3. Depth Measurement Options.

3.a. Platform depth (6, 8, or 10 m) should be used to define dive duration if no other depth measurement device is available.

3.b. Tracking regulator depth is desirable to optimize dive time duration at the Hydrolab. Example: A method of using a surface-floating buoy weighted to the pool deck with marks placed on the line at critical depths can be used. These marks represent the no-decompression limit boundaries as established by Table 1 in JPD 1830.3H. The buoy must be placed next to the training mock-up in a location that both the Flight Surgeon and the Test Safety Officer agree upon. The Flight Surgeon and the Test Safety Officer will monitor the depth of the crew operations. Other methods of depth measurement may be used when jointly agreed to by the resident Flight Surgeon, Test Safety Officer, and consulted members of the Medical EVA Integrated Product Team.

The regulator depth is important in order to calculate the Physiological Depth, which is equivalent to the Equivalent Air Depth in situations where diving on air is performed. An example on how to compute Physiological Depth specific to Hydrolab is provided. The depth from the surface of the water to the bottom of the pool is 8.0 m, but the level of the differential pressure regulator is 0.7 m from the bottom of the pool in an astronaut standing vertical in the water column. Therefore, the depth of the regulator is 7.3 m below the surface of the water. The over-pressure of the suit must also be added. The over-pressure is 5.9 psid above the pressure at the differential pressure regulator.

The Physiological (or Equivalent Air Depth) Depth = $(5.9 \text{ psid} \times 0.70 \text{ m} / \text{psid}) + 7.3 \text{ m} = 11.4 \text{ m}$. You go to the next-deeper depth in the table provided in this attachment, or convert meters to ft (3.28 ft / meter) and use Table 1 of JPD 1830.3H to find a no-decompression limit of 150 minutes for 12.2 m (40 ft).

4. Depth Monitoring.

Most Hydrolab training activities will take place at an optimized depth. The Flight Surgeon and the Test Safety Officer will monitor the depth of crew operations. The Test Safety Officer has the primary responsibility to monitor the depth. If the crewmember's

regulator is obscured or otherwise not observable by reasonable means, then the planned dive time should be shortened appropriately to the next no-decompression dive limit. The Flight Surgeon and Test Safety Officer shall inform the Test Director and Russian Flight Surgeon of this decision. If any of the above individuals do not approve of the placement or layout of the buoy depth gage or cannot reasonably determine regulator depth, then the training time will be based on the deepest possible training depth (usually the pool floor depth).

4.c. Inadvertent depth excursion (copied directly from JSC Policy Directive 1830.3H). An inadvertent depth excursion to a depth deeper than planned represents a significant deviation from the dive's test plan. Use reasonable and prudent measures to prevent inadvertent excursions. In the event of an inadvertent excursion, the following procedures apply:

4.c(1) Cumulative duration of excursions < 5 minutes and maximal PD attained within 10 ft of planned depth: no impact.

4.c(2) If paragraph 4.c(1) does not apply, adhere to rules specified in Table 1 for determination of duration and depth. If the dive can be safely terminated within the No-Decompression Limit specified in Table 1, then terminate the dive before reaching this limit. If the dive cannot be terminated within the No-Decompression Limit, then return as soon as possible to PD = 10 ft (3 m), contact the Medical Officer, and decompress for 35 minutes or as directed by the Medical Officer. This decompression stop can be done with the Orlan suited crewmember out of the water on the pool deck and the suit pressure adjusted to 0.3 atm.

5. No-Decompression Limits for Diving and Surface Intervals for Flying After Diving at Hydrolab.

No-Decompression Dive Limits at Hydrolab

PD or EAD (meters)	FD @ 0.40 Atm (Orlan)	FD @ 0.27Atm (EMU)	No-decompression limit (min)
0 – 6.1	0 – 1.97	0 – 3.30	None
6.1 – 7.6	1.97 – 3.47	3.30 – 4.80	400
7.6 – 9.1	3.47 – 4.97	4.80 – 6.30	240
9.1 – 10.7	4.97 – 6.57	6.30 – 7.90	190
10.7 – 12.2	6.57 – 8.07	7.90 – 9.40	150
12.2 – 15.2	8.07 – 11.07	9.40 – 12.4	100

These tables contain no information that cannot be obtained from Table 1 in JPD 1830.3H. They are just structured to make the information easier to interpret at Hydrolab. PD = Physiological Depth, EAD = Equivalent Air Depth, FD = Facility Depth, SI = Surface Interval, O₂ = 100% oxygen (see JMI 1830.3G for definitions).

NOTE: If the dive is done at the limit of any table entry, then use the next deeper depth. For example, if EAD is exactly at 6.1 meters, then use the 6.1 – 7.6 meter row to define the no-decompression limit.

Hydrolab Surface Intervals for Flying After Diving

PD or EAD (meters)	FD @ 0.40 atm (Orlan)	FD @ 0.27 atm (EMU)	No-deco limit (min)	Dive Duration (min)	Air SI (hrs)	O ₂ SI (min)
0 – 6.1	0 – 1.97	0 – 3.30	None	1 – 60	3	20
0 – 6.1	0 – 1.97	0 – 3.30	None	61 – 100	5	40
0 – 6.1	0 – 1.97	0 – 3.30	None	101 – 400	14	120
0 – 6.1	0 – 1.97	0 – 3.30	None	> 400	24	180
6.1 – 7.6	1.97 – 3.47	3.30 – 4.80	400	1 - 45	3	20
6.1 – 7.6	1.97 – 3.47	3.30 – 4.80	400	46 - 80	5	40
6.1 – 7.6	1.97 – 3.47	3.30 – 4.80	400	81 - 290	14	120
6.1 – 7.6	1.97 – 3.47	3.30 – 4.80	400	291 - 400	24	180
7.6 – 9.1	3.47 – 4.97	4.80 – 6.30	240	1 – 35	3	20
7.6 – 9.1	3.47 – 4.97	4.80 – 6.30	240	36 – 60	5	40
7.6 – 9.1	3.47 – 4.97	4.80 – 6.30	240	61 – 240	14	120
9.1 – 10.7	4.97 – 6.57	6.30 – 7.90	190	1 – 30	3	20
9.1 – 10.7	4.97 – 6.57	6.30 – 7.90	190	31 – 50	5	40
9.1 – 10.7	4.97 – 6.57	6.30 – 7.90	190	51 – 190	14	120
10.7 – 12.2	6.57 – 8.07	7.90 – 9.40	150	1 – 25	3	20
10.7 – 12.2	6.57 – 8.07	7.90 – 9.40	150	26 – 45	5	40
10.7 – 12.2	6.57 – 8.07	7.90 – 9.40	150	46 – 150	14	120
12.2 – 15.2	8.07 – 11.07	9.40 – 12.4	100	1 – 20	3	20
12.2 – 15.2	8.07 – 11.07	9.40 – 12.4	100	21 – 35	5	40
12.2 – 15.2	8.07 – 11.07	9.40 – 12.4	100	36 – 100	14	120

6. Flying After Diving Guidelines for Hydrolab. For situations that are not clearly covered by JPD 1830.3H about flying after diving or altitude chamber exposure after diving, consult with the NASA assigned medical operations Flight Surge before authorizing those activities.